manent endowment of six existing schools in the university, and these schools are to be given the names as follows: The James Madison School of Law, the James Monroe School of International Law, the James Wilson School of Political Science and Political Economy, the Edgar Allan Poe School of English, the Andrew Carnegie School of Engineering, the Walter Reed School of Pathology.

Gifts to Princeton University for the quarter ending with the spring recess aggregated $145,939. $100,000 was presented by Cleveland H. Dodge, '79, of New York, for part of the endowment of Guyot Hall, the new natural science laboratory now under construction on the eastern side of the campus. A fund of $400,000 was presented some time ago for the construction of the building, which is now nearing completion. The next largest gift came from the committee of fifty alumni who are raising funds by subscription for the immediate needs and future development of the university. This committee turned in a total of $38,039 for the quarter, $28,039 of which goes to current expenses and $10,000 for endowment.

Exercises appropriate to the opening of the new engineering building of Rutgers College, erected at a cost of $100,000, were held on April 14. The building contains seven classrooms, five laboratories, six professors' offices, and three draughting rooms. It is used by the departments of civil, electrical and mechanical engineering.

The University of Pennsylvania correspondent of the New York *Evening Post* states that the cosmopolitan character of the student body at the university was emphasized at the recent formation of the Cosmopolitan Club, the object of which is to hold occasional meetings, when an opportunity will be afforded to men of all nationalities to become acquainted with each other, and to discuss matters of common interest. It is planned to hold, next year, a series of "national nights," where the customs of each country will be presented by its representatives. It was found that there are 120 students in the university from the Latin-American countries, 50 students who are British subjects, and 31 who are Chinese. There are 32 other countries represented in the student body.

Dr. A. A. Murphree, president of the State College for Women at Tallahassee, has been elected president of the University of Florida.

Dr. R. C. Hughes has resigned the presidency of Ripon College.

J. F. Messenger, A.B. (Kansas), A.M. (Harvard), Ph.D. (Columbia), professor in the department of psychology and education of the State Normal School at Farmville, Va., has been called to the University of Vermont.

M. Dangeard, editor of the *Botaniste,* professor in the faculty of Poitiers, has been called to a chair in the faculty of sciences at Paris.

DISCUSSION AND CORRESPONDENCE

THE FUNDAMENTAL LAWS OF MATTER AND ENERGY

To the Editor of Science: In a recent number of *The Technology Quarterly* (June, 1908) appears an article by Professor Lewis entitled "A Revision of the Fundamental Laws of Matter and Energy." It closes with the following summary:

> It is postulated that the energy and momentum of a beam of radiation are due to a mass moving with the velocity of light.
>
> From the postulate alone it is shown that the mass of a body depends upon its energy content. It is, therefore, necessary to replace that axiom of the Newtonian mechanics according to which the mass of a body is independent of its velocity by one which makes the mass increase with the kinetic energy.
>
> Retaining all the other axioms of the Newtonian mechanics and assuming the conservation of mass, energy and momentum, a new system of mechanics is constructed.
>
> In this system momentum is mv, kinetic energy varies between $\frac{1}{2}mv^2$ at low velocities and mv^2 at the velocity of light, while the mass of a body is a function of the velocity and becomes infinite at the velocity of light. The equation obtained agrees with the experiments of Kaufmann on the relation

between the mass of an electron and its velocity. It is, moreover, strikingly similar to the equations that have been obtained for electromagnetic mass.

The new view leads to an unusual conception of the nature of light. It offers theoretically a method of distinguishing between absolute and relative motion.

Mass is defined by Professor Lewis as momentum (M) divided by velocity (v),

$$m = M/v.$$

I should like to say a few words about this summary and the paper to which it belongs.

The notion of momentum in a beam of radiation is introduced with the aid of the "law of conservation of momentum." The other two laws required, of the three in all, are the conservation of energy and the conservation of mass.

For the sake of argument, I shall assume a beam of radiation to consist of a mass in motion and proceed to consider the use of such a hypothesis or conception.

What happens when that beam impinges on a body? That the body receives energy and that this energy is shown by the movement of the body is settled beyond doubt by experiment, but that the moving mass in the beam sticks to the body it strikes is very questionable. How can it stick to a body which radiates as much energy as it receives and of the same nature? Professor Lewis does not seem to consider this difficulty. But, for the sake of argument again, I assume that what is mass in the beam of radiation does adhere to the body it strikes. Then, of course, the mass of the body struck increases as it moves and increases as it receives this particular form of energy, but only as it receives *this particular form*. Yet Professor Lewis considers this increase of mass with energy as typical and concludes that because the mass of a body increases as it receives radiant energy, to which he assigns a very special constitution, therefore its mass increases when it receives any energy whatsoever and diminishes when it loses any energy whatsoever. Otherwise, what does the following mean:

> Assuming the fundamental conservation law [of momentum? C. L. S.], we must regard mass as a real property of a body which depends upon its state and not upon its history. Hence it is obvious that if in any other way than by radiation the body gains or loses energy, it must gain or lose mass in just the above proportion [see equation (5) below, C. L. S.]. In other words, any change in a body's content of energy is accompanied by a definite change in its mass, regardless of the nature of the process which the energy change accompanies.

This seems to me equivalent to saying that all energy is of the same nature as radiant energy, a notion not acceptable in the present state of our sciences. Professor Lewis thinks that consequently one of the axioms of Newtonian mechanics must be changed. I suppose he refers to axiom 1, but none of the three says a word about this relation. They imply this independence of mass and velocity, but were they to be found dependent, I can not see that any of the three would be changed, necessarily, in wording. I do not find in this whole development anything more than a special kind of action, one that can not be generalized at all. A ship bombarded by projectiles and moving in the same direction as the projectiles continues in the same direction as before with increased mass and increased velocity due to the mass and energy of those missiles. But who would draw any general conclusions as to the nature of all the other energies from this? It is a very easily analyzed case, but I do not see how it differs in principle from the more obscure one of radiant energy.

The change in mass for a given quantity of energy is calculated by Professor Lewis thus:

The moving mass of the beam imparts dE of energy in dt time, so in t time it imparts $(dE/dt)t$ of energy. During this time t, a quantity of energy has traveled up to the body absorbing the radiation and been delivered to it equal to fs where f is the radiation pressure and s is the distance the radiation has traveled in t time. Making t equal to unity, s becomes the velocity of radiation, V. Then,

$$f = dE/Vdt. \qquad (1)$$

By condition, this f, being due to a moving

mass, imparts momentum dM in time dt and so,

$$f = dM/dt. \quad (2)$$

With (1) and (2),

$$dE/dM = V. \quad (3)$$

But a momentum from a mass dm moving with a velocity V requires that

$$Vdm = dM, \quad (4)$$

and so with (3),

$$dm = dE/V^2. \quad (5)$$

Now equation (5) is a very simple thing. It gives the mass needed at velocity V to produce the energy dE in this special way. But Professor Lewis says this equation gives the *change in mass when the energy of the body changes by dE in any manner whatsoever.* I do not see that this inference is legitimate at all.

In the fourth paragraph there is the startling statement that the mass of a moving body becomes infinite at the velocity of light. It seems to me this at once throws suspicion on the line of reasoning leading up to such a conclusion. Professor Lewis recognizes this difficulty for he says, "Therefore that which in a beam of light has mass, momentum and energy, and is traveling with the velocity of light, would have no energy, momentum or mass if it were at rest, or, indeed, if it were moving with a velocity even by the smallest fraction less than that of light," adding with great naïveté, "After this extraordinary conclusion it would at present be idle to discuss whether the same substance or thing which carries the radiation from the emitting body continues to carry it through space, or, indeed, whether there is *any substance or thing connected with the process.*" (Italics mine, C. L. S.) Moreover, I do not see how this part of the fourth paragraph is consistent with (5). There is no special value, numerically, to be assigned to V in deducing (5) and so there can not be an extraordinary jump from a finite to an infinite value when V has a certain finite value assigned it. We have no right to assume that the velocity of light is the greatest possible velocity in the universe. What would the mass become for a greater velocity? What does the mass become for the lesser velocity of light in water?

It seems to me that there is no need for any such startling conclusion. In fact, no opportunity for it, as I think will be seen from the following.

A beam of radiant energy composed of a moving mass changes the momentum of the body struck by it both by the change in velocity and by the change in mass due to the mass of the beam passing into the body struck by the beam. Hence, from the definition of momentum, $M = mv$,

$$dM = mdv + vdm. \quad (6)$$

Replacing in (4),

$$Vdm = mdv + vdm,$$

or

$$dm/m = dv/(V - v).$$

In this equation, V is the velocity of the striking mass of the beam, the mass of which is dm, while v is the velocity of the object struck whose mass is m, and dv is the velocity imparted to it, to the mass m. Consequently, this equation expresses the relation between the change in mass of the object struck, due to the accretion from the mass of the beam, and v, the velocity of the object, due to the impact of the beam mass. Integrating,

$$m/m^0 = V/(V - v) \quad (7)$$

where m^0 is the mass of the object at rest, that is, when v is zero. When v is V, its mass becomes infinite, which means that a mass aggregating to an infinite mass must accumulate on the object before it will attain a velocity equal to the velocity of the pelting mass of the beam. In other words, the mass of the object must become relatively zero and not absorb any of the kinetic energy of the beam for itself, to increase its motion. This is surely simple! Who would conclude from this that when a body is given a velocity equal that of light in any way whatsoever its mass becomes infinite? Yet this is what Professor Lewis seems to do. He deduces his equation in a somewhat different way, passing through the energy and not through the momentum,

but coming out with an equation of the same nature as 7. As I understand it, he proceeds as follows:

Combining (1) and (2), for any velocity,

$$dE = vdM,$$

and replacing dM from (6) and dE from (5),

$$V^2dm = vmdv + v^2dm.$$

Integrating,

$$m/m^0 = V/\sqrt{V^2 - v^2}, \qquad (8)$$

in which as before, when v is zero, m is m^0, the mass of the object at rest, and when v^2 is V^2, the mass is again equal to infinity, for the same reason as given previously. Professor Lewis interprets this equation thus: "According to equation (8), any body of finite mass increases in mass as it increases in velocity, and would possess infinite mass if it could be given the velocity of light."

Consider a body in a rarefied atmosphere and set in motion by the gas particles. It seems to me that Professor Lewis's reasoning will apply equally here, and then a body moving with the velocity of the gas particles should gain infinite mass. According to my interpretation of the equations, when the body did gain the velocity of the gas particles, an infinite number of them, an infinite mass, would have accumulated on the object.

I am inclined to think myself that these troubles of mine are due to unfortunate wording. If so, Professor Lewis ought to make the thing clearer, as it is very important, and I am sure many others have the same difficulty I have in harmonizing the article with one's experiences and reasoning powers.

CLARENCE L. SPEYERS

CAMBRIDGE, MASS.,
December 14, 1908

MARS AS THE ABODE OF LIFE[1]

ALTHOUGH it is improbable that these lines will be read by more than a small proportion of those who have seen or heard of Mr. Percival Lowell's "Mars as the Abode of Life," it seems worth while to point out to the scientific workers of the country the gross errors which this book is propagating. In this I shall confine myself to geological matters, leaving the astronomical and other questions to those who have special acquaintance with such things. It is not surprising that Mr. Lowell, an astronomer, should have only a layman's knowledge of geology; but that he should attempt to discuss critically the more difficult problems of that science, without, as his words show, any understanding of the great recent progress in geology, is astonishing and disastrous. One can not but recall the adage that "fools rush in where angels fear to tread."

Mr. Lowell is an implicit believer in the Laplacian theory of planetary evolution, a hypothesis now on the defensive, to say the least, and utterly abandoned by some of our best cosmogonists.

On an adjacent page he says that the minerals of the metamorphic rocks "show by their crystalline form that they cooled from a once molten state." The fallacy in this statement is evident to the average college student of geology or chemistry. Metamorphic rocks are produced by processes which involve more or less pressure and heat, but not melting.

Turning to consider the evolution of life on the earth, the author tells us that "the geologic record proves that life originated in the oceans. . . . Whether life might have generated on the land we do not know; on earth it certainly did not." The truth is that the geologic record proves nothing whatever about the origin or even the infancy of life. It may be fairly doubted whether it takes us back even to the middle age of the animal kingdom. Such a dogmatic assertion is, therefore, wholly unjustified. In this connection it is hard to resist pointing out that among the oldest known fossils are certain Eurypterids (Walcott's *Beltina danai*) which are generally interpreted as fresh-water rather than marine forms.

Farther on we read, of the plants which formed the Carboniferous coal beds, "Only a warm, humid foothold and lambent air could have given them such luxuriance and im-

[1] A series of lectures delivered before the Lowell Institute, Boston; later published in the *Century Magazine*, 1908; and subsequently issued as a volume by the Macmillan Company, New York, 1908.